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EXECUTIVE SUMMARY

Global carbon emissions must be halved by 2030 to limit warming to 1.5°C and avoid catastrophic climate impacts. The U.S. transportation sector is the country's largest carbon emitter and a challenging piece of the decarbonization puzzle. Fortunately, recent advances in electric vehicle (EV) battery cost and performance, range, and recharging—along with a proliferation of vehicle models—have readied EVs to overtake gasoline and diesel vehicles as the dominant on-road technology. Now that the plummeting cost of wind and solar power have enabled a rapid and cost-effective expansion of a clean electricity grid, a cost-effective pathway to decarbonize the transportation sector is in reach. Yet electric vehicles make up only a small part of today's U.S. vehicle fleet, and many sales projections for the next decade are modest. Several hurdles, including high upfront vehicle costs and inadequate charging infrastructure, rather than technical or economic feasibility, are the largest barriers to EV sales growth and accelerated decarbonization to align with global climate targets.

In this report, we analyze the economic, human health, environmental, and electric grid impacts of a future in which ground transportation is all-electric. Our main scenario, the Drive Rapid Innovation in Vehicle Electrification (DRIVE Clean) scenario, represents a future in which EVs constitute 100% of new U.S. light-duty vehicle (LDV) sales by 2030 as well as 100% of medium-duty vehicle (MDV) and heavy-duty truck (HDT) sales by 2035. The grid reaches 90% clean electricity by 2035, and substantial EV charging infrastructure is deployed. We compare this scenario to a No New Policy scenario, in which EVs constitute 45% of new LDV sales, 38% of MDV sales, and 12% of HDT sales in 2035, and the clean electricity share reaches only 47% by 2035. By demonstrating that the ambitious DRIVE Clean goals are technically feasible and economically beneficial, we aim to inform broader discussions of the U.S. transportation transition. Following are key findings from our analysis.

CONSUMER SAVINGS FROM EV OWNERSHIP START SOON AND GROW RAPIDLY

Historically, EV sales have been hindered by two consumer-cost disadvantages: the total cost of ownership (TCO) and upfront prices of EVs have both been high in relation to internal combustion engine (ICE) vehicles. Our results show, however, that electric heavy-duty trucks already hold a TCO advantage today, and light-duty EVs will overtake ICE vehicles in TCO terms within 5 years (Figure ES-1). In addition, light-duty EVs will reach upfront price parity with their ICE counterparts in the mid- to late-2020s, while electric HDTs will approach upfront price parity with diesel trucks in the mid- to late-2030s. However, the persistence of high upfront EV costs is a major barrier to achieving rapid decarbonization of the transportation sector. At a national level, the DRIVE Clean scenario yields cumulative economic savings of approximately $2.7 trillion through 2050 compared to the No New Policy scenario — an average household savings of approximately $1,000 per year over the next 30 years. The DRIVE Clean scenario's electrification of light-duty EVs by 2030 is critical to the benefits realized, saving $460 billion more than a scenario in which 100% light-duty EV sales are achieved 5 years later.

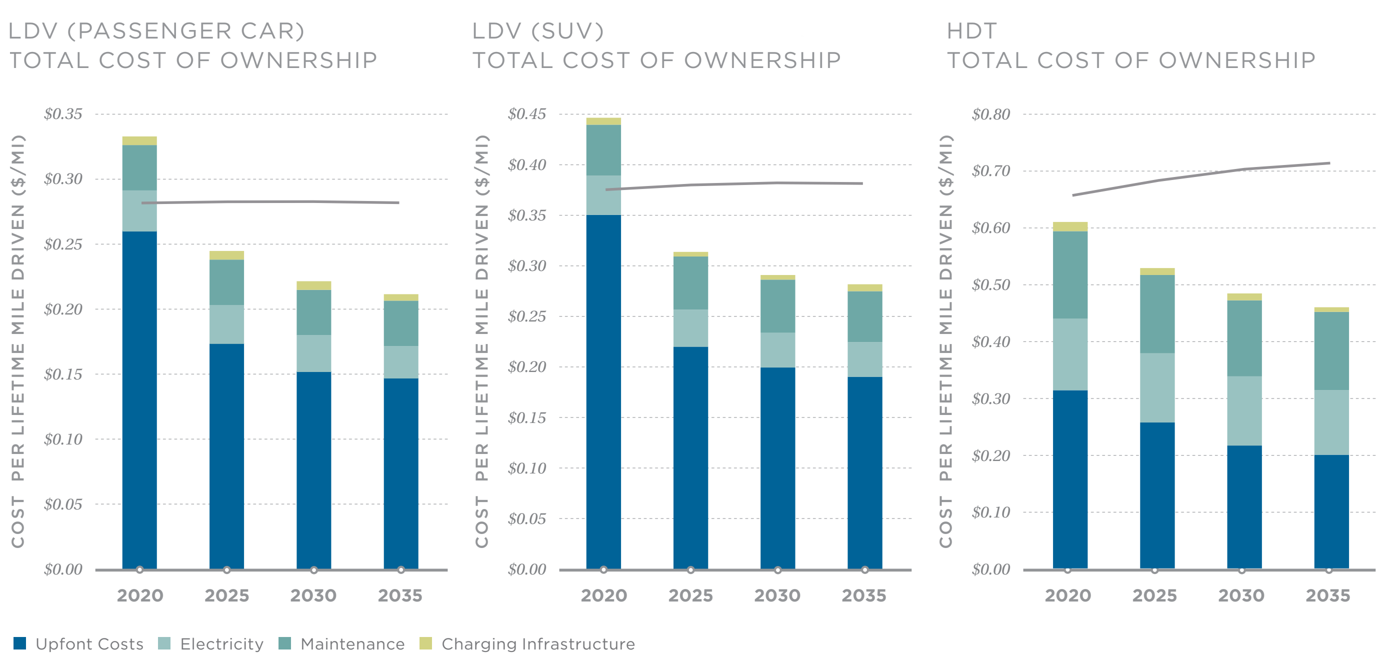

FIGURE ES-1.

TCO for EVs (bars) vs. ICE vehicles (lines), showing TCO parity achieved by 2023 for LDVs (left and center) and an existing TCO advantage for HDTs (right). Upfront costs include taxes. Maintenance costs of EVs include battery replacement cost.

ACCELERATING EV ADOPTION SAVES 150,000 LIVES, AVOIDS $1.3 TRILLION IN HEALTH AND ENVIRONMENTAL DAMAGES THROUGH 2050

Gasoline- and diesel-powered vehicles harm human health and the environment via emissions of pollutants such as fine particulate matter, nitrogen oxides, and sulfur oxides as well as greenhouse gas emissions that contribute to climate change. These emissions disproportionately impact low-income communities and communities of color. Compared with the No New Policy scenario, the total transportation sector pollutant and carbon dioxide (CO_2) emissions reductions in the DRIVE Clean scenario avoid approximately 150,000 premature deaths and equate to nearly $1.3 trillion in health and environmental savings through 2050 (Figure ES-2). The DRIVE Clean scenario slashes ground transportation sector CO_2 emissions by 60% in 2035 and by 93% in 2050, relative to 2020 levels. Total transportation sector emissions fall by 48% in 2035 and by 75% in 2050, relative to 2020 levels (Figure ES-3).

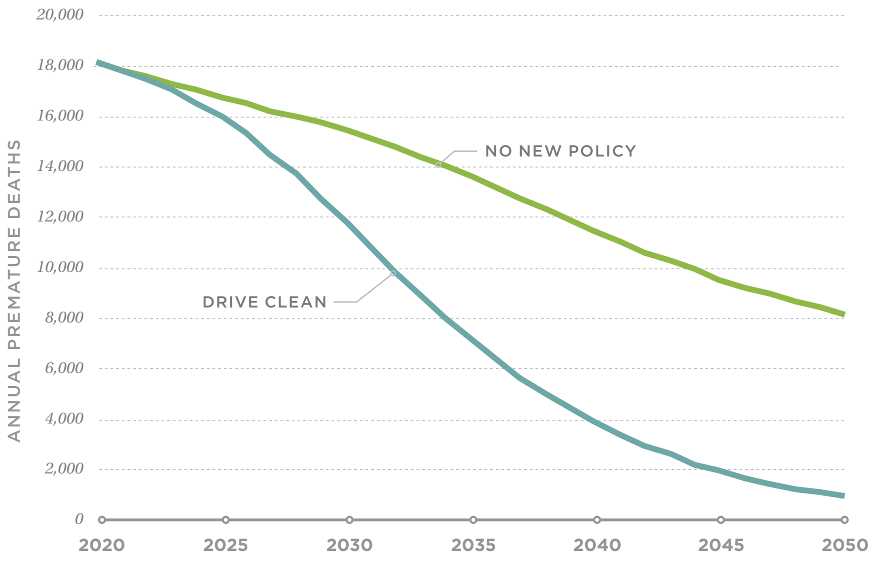

FIGURE ES-2.

Annual premature deaths in the No New Policy and DRIVE Clean scenarios, 2020–2050. The DRIVE Clean scenario avoids 150,000 premature deaths due to air pollution through 2050.

CO_2 EMISSIONS IN THE TRANSPORTATION SECTOR

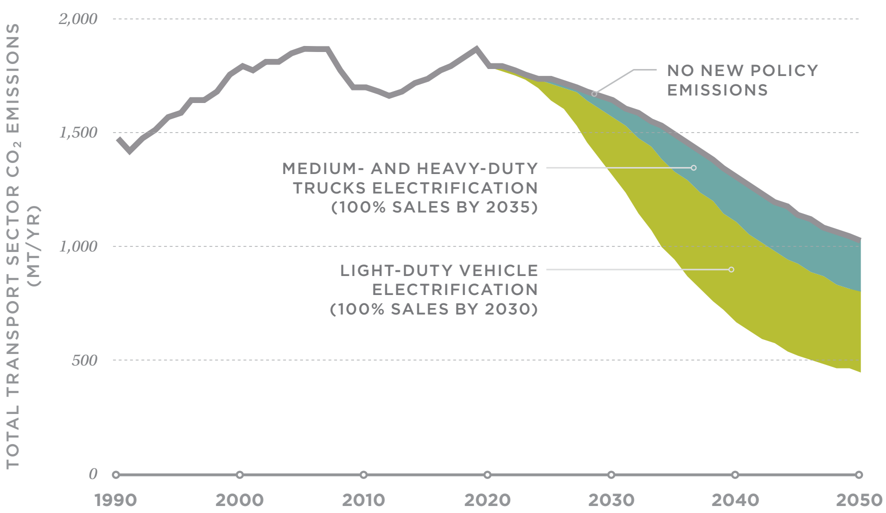

FIGURE ES-3.

Transportation sector CO_2 emissions in the DRIVE Clean and No New Policy scenarios through 2050.

THE ELECTRIC VEHICLE TRANSITION SUPPORTS EMPLOYMENT OPPORTUNITIES ACROSS THE ECONOMY

The DRIVE Clean scenario supports consistent job gains in 2020-2035, peaking at over 2 million jobs in 2035 compared to the No New Policy scenario (Figure ES-4). Employment gradually ramps up in this timeframe as electric vehicle manufacturing expands and the electric grid adds new renewable energy and battery storage resources to support increased vehicle electrification. Consumer cost savings in the transition to electric vehicles similarly increases induced jobs in the economy. While electric vehicles require less maintenance and have fewer parts, the reduction in auto repair jobs is more than offset by gains in economy-wide induced jobs and increased power sector jobs.

NET JOBS IN 2035 — DRIVE CLEAN SCENARIO

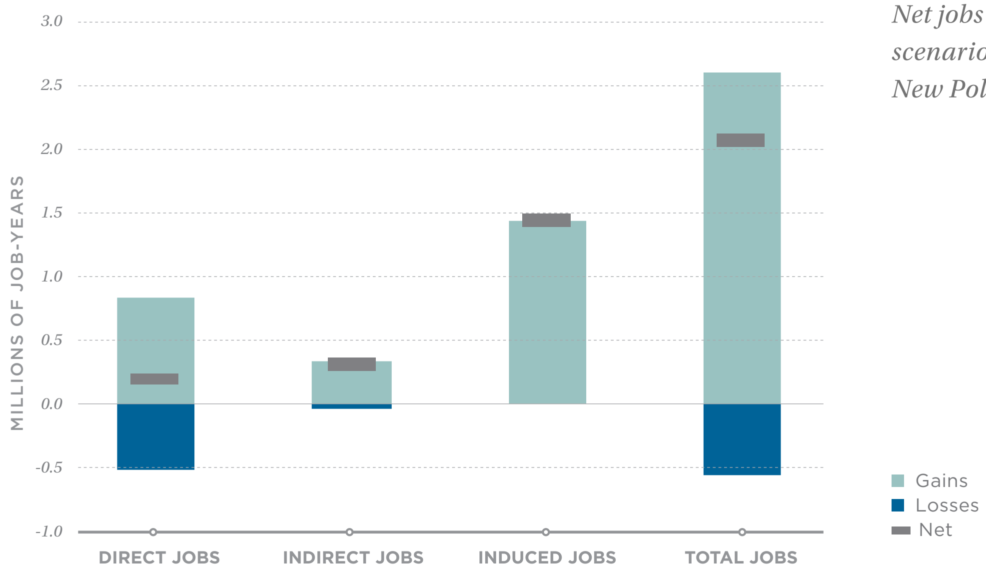

FIGURE ES-4.

Net jobs in 2035, DRIVE Clean scenario compared to the No New Policy scenario.

EV PERFORMANCE AND AVAILABILITY CAN MEET THE NEEDS OF AMERICAN DRIVERS

American drivers have become accustomed to the vehicle performance and availability standards established by gasoline- and diesel-powered vehicles for vehicle range, fueling time, diversity of vehicle models, and—for commercial vehicles—weight. EVs have been improving rapidly across all these dimensions, and our analysis suggests they will not present significant barriers to the accelerated EV deployment envisioned in the DRIVE Clean scenario.

REQUIRED CHARGING INFRASTRUCTURE CAN BE BUILT COST-EFFECTIVELY TO SERVE THE ENVISIONED EV FLEET

To enable the DRIVE Clean scenario, U.S. EV-charging infrastructure must provide drivers with at least as much convenience as provided by existing gasoline and diesel fueling stations. We find that the pace of the required infrastructure scaleup is challenging but achievable, and the costs are modest compared with the benefits of widespread EV deployment. Each year over the next 30 years, the United States must install an average of approximately 270,000 public chargepoints for LDVs and 35,000 MDV/HDT chargepoints. The rate of installation is comparable to historical rates achieved in other rapidly electrifying regions. The cumulative investment in public charging infrastructure ($6.5 billion per year) makes up a small portion of EV TCO in the DRIVE Clean scenario (Figure ES-1).

GLOBAL AND DOMESTIC SUPPLY CHAINS CAN SATISFY ACCELERATED EV AND BATTERY PRODUCTION, LED BY U.S. COMPANIES

With strong policy support, domestic and global EV manufacturing capacity can sufficiently scale to meet the DRIVE Clean goals. In addition, accelerated U.S. EV deployment will present opportunities for U.S. manufacturing leadership in an increasingly competitive global context. The DRIVE Clean scenario requires that annual U.S. electric LDV sales grow from 331,000 to over 15 million by 2030. Domestic manufacturing of these vehicles is beginning to ramp up, with significant investments from manufacturers such as Ford and General Motors. At the same time, more than 125 zero-emission MDVs and HDTs are in production or development in the United States. Similarly, the DRIVE Clean scenario will depend on at least 1,200 GWh of battery capacity per year by 2035. While current global lithium-ion battery demand is about 300 GWh, global battery manufacturing capacity is expected to exceed 2,000 GWh by 2028. Strong policy will be necessary to further develop domestic vehicle and battery manufacturing capacity, encourage raw material procurement and cost-competitive battery recycling, and help the U.S. compete globally.

ELECTRIC GRID IMPACTS OF THE ENVISIONED EV FLEET ARE MANAGEABLE

Even with additional electric loads in the DRIVE Clean scenario, the 90% clean grid is dependable without coal plants or new natural gas plants by 2035. In addition, the resulting wholesale electricity cost is lower than today's costs. Under the DRIVE Clean scenario, all existing coal plants are retired by 2030, no new fossil fuel plants are built, and electricity demand growth from increased electrification averages about 2% per year, a growth rate slower than that achieved in 1975-2005 (Figure ES-5). To meet this demand, the United States must install on average 105 GW of new wind and solar and 30 GW of new battery storage each year—nearly four times the current deployment rate in the U.S., but lower than that achieved by China in 2020 (Figure ES-6).

During normal periods of demand, the combination of existing hydropower and nuclear capacity, approximately half of existing fossil fuel capacity, and new battery storage, wind, and solar is sufficient to meet load dependably with a 90% clean grid. During periods of high demand and/or low renewable generation, existing natural gas plants (primarily combined-cycle plants) cost-effectively compensate for remaining mismatches between demand and renewables-plus-battery generation—accounting for about 10% of total annual electricity generation. Although new investments in the distribution system are necessary to support increased load from electric vehicles, the costs are modest. Because electricity sales are increasing due to electrification, the increased distribution costs are spread across more units of electricity, which results in lower costs to consumers on a per kWh basis. We do not analyze the benefits of managed or "smart" charging. However, existing literature suggests that EVs can serve as flexible loads, helping to reduce bulk system and distribution system costs.

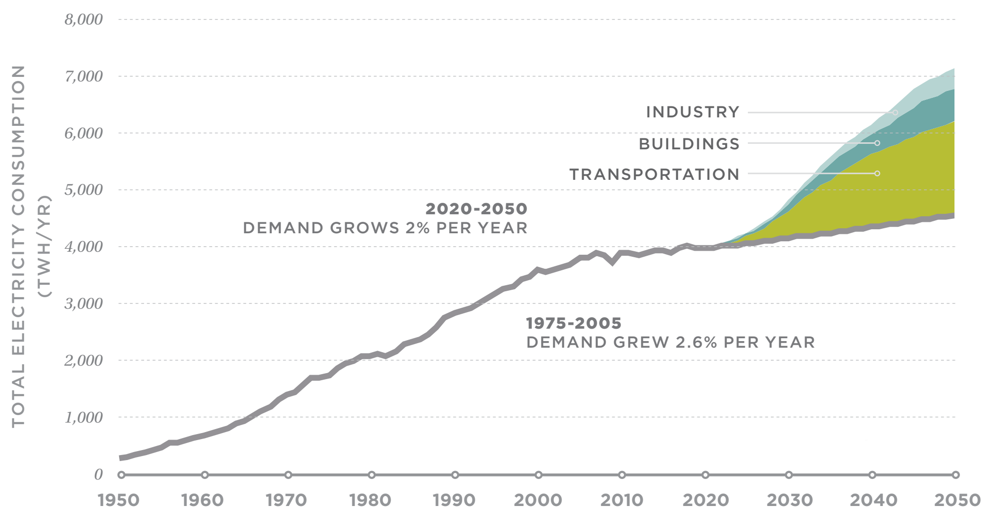

FIGURE ES-5.

Historical and average annual U.S. electricity demand growth in the DRIVE Clean scenario, 2020–2050.

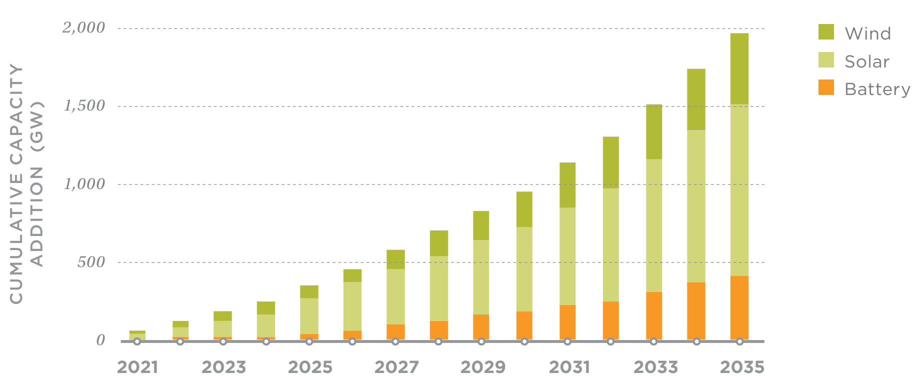

FIGURE ES-6.

U.S. electricity capacity additions in the DRIVE Clean scenario, 2021–2035.

ACCELERATING TRANSPORTATION ELECTRIFICATION: THE CRITICAL ROLE OF A POLICY ECOSYSTEM

Plummeting battery costs, breakthroughs in battery technology, and dramatic declines in clean energy costs have accelerated the timeline for cost-effective transportation decarbonization. Significant barriers remain, but the total consumer cost savings and societal benefits of accelerated vehicle electrification are staggering. Achieving the goal of the DRIVE Clean scenario puts the United States on a 1.5°C pathway for economy-wide decarbonization while yielding substantial human health and environmental benefits and saving consumers $2.7 trillion in vehicle spending—approximately $1,000 in average household savings each year—over the next 30 years. If light-duty vehicle electrification is delayed to 2035 in accordance with many currently proposed transportation electrification goals, we leave significant cost savings on the table. When it comes to electrifying transportation, sooner is definitely better.

New policies and regulations will be needed to achieve the accelerated 100% electric vehicle sales goal. A companion report from Energy Innovation details the policy and regulatory changes that could enable the electric vehicle and charging-infrastructure deployment necessary to equitably decarbonize ground transportation.